OROVILLE FERC RELICENSING
(PROJECT NO. 2100)

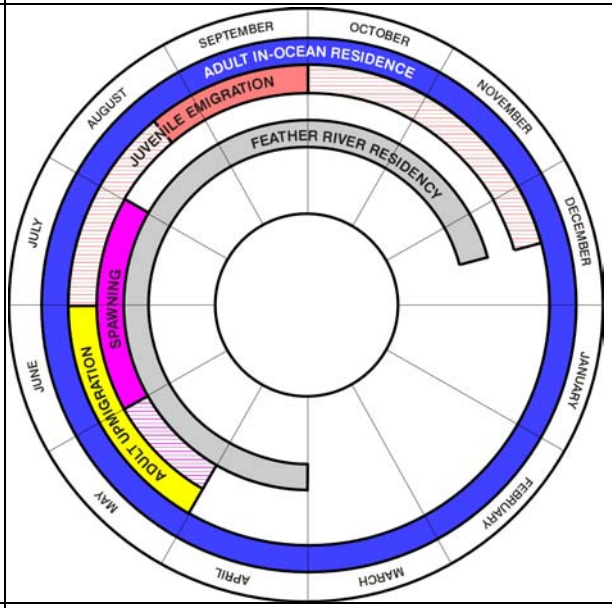
INTERIM REPORT
SP-F3.2 TASK 2
SP-F21 TASK 1

APPENDIX A
MATRIX OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES

LITERATURE REVIEW OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES

AMERICAN SHAD

JANUARY 2003

Element	Element Descriptor	General	Feather River Specific
General			
common name (s)	English name (usually used by fishers and laypeople).	American shad	
scientific name (s)	Latin name (referenced in scientific publications).	*Alosa sapidissima* (Wilson)	
taxonomy (family)	Common name of the family to which they belong. Also indicate scientific family name.	Herrings – *Clupeidae*	
depiction	Illustration, drawing or photograph.		
range	Broad geographic distribution, specifying California distribution, as available.	American shad are native to the Atlantic Coast, from Labrador to the St. Johns River, Florida (Moyle 2002). On the west Coast, where American shad were introduced, they range from Kodiak Island, Alaska, to Todos Santos Bay, Baja California (Painter et al. 1979).	The main shad runs in California are in the Sacramento River up to Red Bluff, and in the lower reaches of its major tributaries, particularly the American, Feather, and Yuba rivers (Moyle 2002).

Element	Element Descriptor	General	Feather River Specific
native or introduced	If introduced, indicate timing, location, and methods.	American shad were introduced in 1871, when 10,000 fry were transported from New York and released into the Sacramento River near Tehama, California. Within 8 years, American shad were appearing in San Francisco markets (Painter et al. 1979). Between 1871 and 1881, more than 800,000 American shad fry from New York were planted in the Sacramento River (Moyle 2002).	
ESA listing status	Following the categories according to California Code of Regulations and the Federal Register, indicate whether: SE = State-listed Endangered; ST =State-listed Threatened; FE = Federally listed Endangered; FT = Federally-listed Threatened; SCE = State Candidate (Endangered); SCT = State candidate (Threatened); FPE = Federally proposed (Endangered); FPT = Federally proposed (Threatened); FPD = Federally proposed (Delisting); the date of listing; or N = not listed.	American shad is not listed.	
species status	If native, whether: Extinct/extirpated; Threatened or Endangered; Special concern; Watch list; Stable or increasing. If introduced, whether: Extirpated (failed introduction); highly localized; Localized; Widespread and stable; Widespread and expanding.	American shad are anadromous, and are widespread and stable (Moyle 2002). In the 1970s, the American shad spawning population was estimated at approximately 3 million fish, about one-third of the number that existed 60 years earlier. Indices of juvenile American shad have declined steadily since 1977 and sport fishing catches appear down (Moyle 2002).	

Element	Element Descriptor	General	Feather River Specific
economic or recreational value	Indicate whether target species sought for food or trophy. Whether desirable by recreational fishers, commercial fishers, or both.	American shad have high recreational and economic value (Froese et al. 2002).	As of the 1970s, popular shad angling areas in central California were the Sacramento, American, Feather and Yuba rivers (Painter et al. 1979).
warmwater or coldwater	Warmwater if suitable temperature range is similar to basses; coldwater if suitable temperature range is similar to salmonids.	American shad are a coldwater fish (Moyle 2002).	
pelagic or littoral	Environment: Pelagic - living far from shore; Littoral - living near the shore.	American shad are pelagic (Froese et al. 2002; Wang J. 1986).	
bottom or water column distribution	Environment: bottom (benthic) or along water column.		
lentic or lotic	Environment: Lentic - pertaining to stagnant water, or lake-like; Lotic - moving water, or river-like.	American shad are found in lotic environments (Moyle 2002).	
Adults			
life span	Approximate maximum age obtained.	American shad live for up to 11 years in Atlantic populations (Painter et al. 1979). In California, there is no record of American shad living longer than 7 years (Moyle 2002).	In Sacramento River, may reach 7 years (Wixom 1979)
adult length	Indicate: Length at which they first reproduce; average length and maximum length the fish can attain.	American shad can reach 30 inches (75 cm) in length, and is a relatively large species compared to other clupeids (Moyle 2002). American shad can reach 23 inches (58.4 millimeters) long (Stier et al. 1985). In the Yuba River, American shad at 3 years of age are 16.5 inches (42 centimeters) long, and are 18.9 inches (48 centimeters) long by their year 7 (Moyle 2002). American shad mature at a minimum of 2 years	In the Sacramento River, American shad males mature in 3 to 4 years (first time spawners); females mature in 4 to 5 years. American shad may precociously mature at 2 years (Wixom 1979).

Element	Element Descriptor	General	Feather River Specific
		of age; the mean age at maturity for males is 4.3 years and they range from 12 to 16 inches (305-447 millimeters) in length; the mean age at maturity for females is 4.6 yrs and they range from 15.1 to 19.1 inches (383-485 millimeters) in length (Stier et al. 1985).	
adult weight	Indicate: Weight at which they first reproduce; average weight and maximum weight the fish can attain.	In the Atlantic, the maximum recorded weight of an American shad is 15 pounds (6804 grams) at 29.9 inches (76 centimeters) (Froese et al. 2002). Atlantic American shad populations length-to-weight relationship is: weight = $0.0065*length^{2.959}$ (Froese et al. 2002).	
physical morphology	General shape of the fish: elongated, fusiform, laterally compressed, etc.	American shad are fusiform in shape.	
coloration	Indicate color, and color changes, if any, during reproduction phase.	American shad are steely blue on the backs and silvery on the sides (Moyle 2002).	
other physical adult descriptors	Unique physical features for easy identification.	American shad are distinguished by a row of 4 to 6 black spots on the back just behind the operculum (Moyle 2002).	
adult food base	Indicate primary diet components.	The diet of adult American shad consists primarily of copepods and mysids, supplemented by small quantities of other planktonic crustaceans and some small fishes (Stier et al. 1985). In the Delta, the most abundant organism found in the stomachs of adult American shad is mysid shrimp, followed by copepods, cladocerans, amphipods, clams, and fish larvae (Moyle 2002).	
adult feeding habits	Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder.	In the Delta, adult American shad feed in freshwater, likely as a result of the abundance of large zooplankters. However, feeding virtually ceases once they enter main rivers (Moyle 2002). Adult American shad are primarily plankton feeders, and characteristically swim with their mouths open and gill covers extended, straining the water for food (Stier et al. 1985).	

Element	Element Descriptor	General	Feather River Specific
adult in-ocean residence time	For anadromous species, age when they migrate to the ocean and duration spent in the ocean before returning to freshwater to spawn.	In Atlantic populations, American shad spend 3 to 4 years in the ocean (Painter et al. 1979). In California populations, American shad spend 3 to 5 years in the ocean (Moyle 2002). American shad spend 2 to 6 years in the ocean (Stier et al. 1985).	
adult habitat characteristics in-ocean	For anadromous species, description of the ocean habitat utilized: whether along major current systems, gyres, pelagic (beyond continental shelves) and neritic (above continental shelves) zones, etc.	American shad spend 3 to 5 years at sea; what happens between their emigration to the sea and their return to spawn is largely unknown (Moyle 2002). Non-spawning adult American shad are found in schools near the surface of the continental shelf waters in the spring, summer, and fall (Froese et al. 2002).	
Adult upstream migration (immigration)			
range of adult upstream migration timing	Time of year adults migrate upstream. If applicable, indicate for various runs.	Mature American shad migrate either north or south from the Atlantic Ocean to their natal streams to spawn. Upstream migrations in southern streams occur early in the spring and progressively later northward (Painter et al. 1979). On the west coast, migration of American shad begins between March and May, when water temperatures exceed 57ºF (14ºC), and extends into early July. In the Sacramento River, American shad do not spawn until water temperatures reach 62.6ºF to 75.2ºF (17ºC to 24ºC) (Moyle 2002).	The upstream migration of American shad in the Sacramento River-San Joaquin River estuary takes about 3 months, occurring in March, April, and May (Painter et al. 1979).
peak adult upstream migration timing	Time of year most adults migrate upstream. If applicable, indicate for various runs.	On the east coast, mature American shad migrate in the spring (Painter et al. 1979). In the Sacramento River, large runs of American shad occur in late May to early June (Moyle 2002).	American shad migrate in the spring (Painter et al. 1979). In the Feather and Yuba rivers, peak migration of American shad occurs in June (U.S.Fish and Wildlife Service 1995).

Element	Element Descriptor	General	Feather River Specific
adult upstream migration water temperature tolerance	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	American shad may discontinue the upstream migration if water temperatures exceed 68ºF (20ºC) (Stier et al. 1985).	
adult upstream migration water temperature preference	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.	In the Columbia River, 90 percent of the spawning run takes place when river water temperatures are 60.8ºF to 67.1ºF (16.0ºC to 19.5ºC) (Leggett et al. 1972). Peak migration of American shad occurs when water temperatures are in the range of 59ºF to 68ºF (15º to 20ºC) (U.S. Fish and Wildlife Service 1995). In the Sacramento River, peak migration of American shad occurs when water temperatures are 62.6ºF to 75.2ºF (17ºC to 24ºC) (Moyle 2002).	In the Sacramento-San Joaquin Delta, American shad migrated upstream when water temperatures were between 57.2ºF and 66.2ºF (14.0ºC and 19.0ºC) during the 1976 and 1977 investigations (Painter et al. 1979).
Adult holding (freshwater residence)			
water temperature tolerance for holding adults	Range of water temperatures allowing survival. Indicate stressful or lethal levels.		
water temperature preference for holding adults	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.		
water depth range for holding adults	Reported range of observed (minimum and maximum) water depth utilization.		
water depth preference for holding adults	Reported range of most frequently observed water depth utilization.		
substrate preference for holding adults	If bottom dwellers, indicate substrate: mud, sand, gravel, boulders, aquatic plant beds, etc. If gravel, indicate range or average size of gravel.		

Element	Element Descriptor	General	Feather River Specific
water velocity range for holding adults	Reported range of observed (minimum and maximum) water velocity utilization.		
water velocity preference for holding adults	Reported range of most frequently observed water velocity utilization.		
other habitat characteristics for holding adults	General description of habitat (e.g. turbid or clear waters, lentic or lotic, presence of aquatic plant beds, debris, cover, etc.).		
timing range for adult holding	Time of year (earliest-latest) and duration of stay from upstream migration to spawning.	On the Atlantic coast, adult American shad require 2 to 3 days of salinity acclimation, as illustrated by their meanderings in estuaries before entering rivers (Stier et al. 1985).	
timing peak for adult holding	Time of year when maximum number of adults are present before spawning.		
Spawning			
fecundity	Average or range in the number of eggs females lay in a spawning season.	In Millerton Reservoir, California, a landlocked population of American shad produces between 98,600 and 225,600 eggs. American shad on the east coast produce between 116,000 and 468,000 eggs. High fecundity may be due to low fertilization rates (only 2 percent of eggs collected had been fertilized in Millerton Reservoir) (Moyle 2002). From various sources, American shad produce between 2,000 and 300,000 eggs (Wang J. 1986). Relative and absolute fecundities decrease as the proportion of repeat American shad spawners increases (Leggett et al. 1978).	
nest construction	Location and general description of nest -- substrates, aquatic plants, excavations, crevices, habitat types, etc.	American shad usually spawn over sand and gravel in the main channels of rivers (Moyle 2002).	

Element	Element Descriptor	General	Feather River Specific
nest size	Size and average dimensions of the nest.		
spawning process	Indicate whether nest builder, broadcast spawner, or other.	American shad are broadcast spawners. In the San Joaquin River above Millerton Reservoir, American shad spawning peaks after dark, taking place between 2100 and 0700 hours, and peaks between 2300 – 0400 hours (Moyle 2002). American shad broadcast their eggs in the water, usually near the surface, where they are fertilized (California Department of Fish and Game 1975).	
spawning substrate size/characteristics	Range of substrates used during spawning (e.g. mud, sand, gravel, boulders, beds of aquatic plants). Indicate presence of plant/wood debris, crevices at spawning sites. If gravel, indicate range of average size.	American shad spawn on broad flats and in shallow waters, generally consisting of sand and gravel (Painter et al. 1979); Moyle 2002).	
preferred spawning substrate	Indicate preferred spawning substrate (e.g. mud, sand, gravel, boulders, plant bed, etc).	American shad prefer to spawn over sand and gravel (Moyle 2002; U.S. Fish and Wildlife Service 1995; Wang J. 1986).	
water temperature tolerance for spawning	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	American shad spawning water temperatures range from 46.4ºF to 78.8ºF (8ºC to 26ºC) (Painter et al. 1979; Wang J. 1986), and range from 53.6ºF to 62.6ºF (12°C to 17°C) in the upper San Joaquin River (Wang J. 1986). The water temperature range for American shad spawning is 60°F to 75°F (U.S. Fish and Wildlife Service 1995).	
water temperature preference for spawning	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	American shad prefer water temperatures ranging from 57.2°F to 69.8°F (14°C to 21°C) for spawning (Painter et al. 1979). In the Sacramento River, American shad prefer water temperatures ranging from 62.6°F to 75.2°F (17°C to 24°C) for spawning (Moyle 2002).	In the Feather River, the reported optimal water temperatures for American shad spawning and egg survival are between 60.1ºF and 70ºF (15.6ºC and 21.1ºC) (Painter et al. 1979).

Element	Element Descriptor	General	Feather River Specific
		In both Atlantic and Pacific coast populations, American shad prefer water temperatures of 65.3ºF (18.5ºC) for spawning (Leggett et al. 1972). American shad prefer water temperatures ranging from 62ºF to 68ºF (16.7ºC to 20ºC) for spawning (U.S. Fish and Wildlife Service 1995).	
water velocity range for spawning	Minimum and maximum speed of water current the spawning fish can tolerate.	The water velocity range for American shad spawning is 1 to 3 feet per second (0.3 to 0.93 meters per second) (Stier et al. 1985). The water velocity range for American shad spawning is 0.5 to 2 feet per second (0.15 to 0.61 meters per second) (Painter et al. 1979). The water velocity range for American shad spawning is 1 to 3 feet per second (0.31 to 0.91 meters per second) (Moyle 2002).	
water velocity preference for spawning	Preferred water current (flow velocity) during spawning.	American shad prefer moderate currents for spawning (Painter et al. 1979). In the Yuba River, American shad prefer water velocities ranging from 1.5 to 2.4 feet per second (0.46 to 0.73 meters per second) for spawning (U.S. Fish and Wildlife Service 1995).	
water depth range for spawning	Reported range of observed (minimum and maximum) water depth utilization.	American shad spawn at water depths ranging from 3 to 40 feet (0.9 to 12.2 meters) (Moyle 2002; Painter et al. 1979). American shad spawn at water depths ranging from 3 to 30 feet (U.S. Fish and Wildlife Service 1995).	
water depth preference for spawning	Reported range of most frequently observed water depth utilization.	American shad prefer to spawn at depths less than 9.8 feet (3 meters) (Moyle 2002).	

Element	Element Descriptor	General	Feather River Specific
range for spawning timing	Earliest and latest time of season or year in which spawning occurs.	In the Sacramento River, American shad spawn in May or early June, when water temperatures reach 62.6ºF to 75.2ºF (17ºC to 24ºC) (Moyle 2002). In the Columbia River, American shad spawn soon after entering the river (Quinn et al. 1996). In the Sacramento-San Joaquin river system, American shad spawn from April through July (Wang J. 1986).	
peak spawning timing	Time of year most fish start to spawn.	In the Sacramento-San Joaquin river system, peak American shad spawning occurs in June and July (Wang J. 1986).	
spawning frequency (iteroparous/semelparous)	Semelparous - producing all offspring at one time, such as in most salmon. Usually these fish die after reproduction. Iteroparous - producing offspring in successive, e.g., annual or seasonal batches, as is the case in most fishes.	American shad spawn annually (Painter et al. 1979). American shad are iteroparous. First-time spawning occurs when males are 3 to 4 years old and females are 4 to 5 years old. The oldest known American shad spawners are 7 years old, but 70 percent of each run is comprised of first-time spawners (virgin shads) (Moyle 2002). American shad fecundity decreases for repeat spawners (Stier et al. 1985).	
Incubation/early development			
egg characteristics	Shape, size, color, in clusters or individuals, stickiness, and other physical attributes.	American shad eggs are spherical and are 0.10 to 0.15 inches (2.5 to 3.8 millimeters) in diameter (Wang J. 1986). American shad eggs are initially adhesive and later become non-adhesive. Unfertilized eggs are approximately 0.07 inches (1.8 millimeters) in diameter and have a pale amber wrinkled egg capsule. Fertilized eggs are 0.09 to 0.15 inches (2.5 to 3.8 millimeters) in diameter and are transparent, pale pink, or amber in color. American shad eggs are slightly heavier than water and are carried by the currents and gradually sink (Stier et al. 1985).	

Element	Element Descriptor	General	Feather River Specific
water temperature tolerance for incubation	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	American shad eggs hatch in 4 to 6 days at water temperatures ranging from 59°F to 64.4°F (15ºC to18ºC) (Painter et al. 1979). Under lab conditions, the American shad incubation/temperature relationship is Y = 729.06 – 8.75 X (r = 0.93), where Y is the number of hours required for hatching and X is the mean water temperature for development (Painter et al. 1979). American shad eggs hatch at water temperatures ranging from 52°F to 80°F (U.S. Fish and Wildlife Service 1995).	In the Feather River, reported optimal temperatures for spawning and egg survival are between 60.1ºF and 70ºF (15.6ºC and 21.1°C) (Painter et al. 1979).
water temperature preference for incubation	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	Hatching of American shad eggs takes 6 to 8 days at 62.6°F (17°C) and takes 8 to 12 days at 51.8ºF to 59ºF (11ºC to 15ºC) (Moyle 2002). American shad eggs require water temperatures ranging from 60°F to 79°F (15.6°C to 26.1°C) for maximum survival (U.S. Fish and Wildlife Service 1995).	
time required for incubation	Time duration from fertilization to hatching. Note: Indicate at which temperature range. Incubation time is temperature-dependent.	Various studies indicate that eggs hatched in 4 to 6 days at water temperatures ranging from 59ºF to 64.4ºF (15ºC to 18ºC); 96 hours at water temperatures ranging from 60.8ºF to 62.6ºF (16ºC to 17ºC); and 6 to 12 days at water temperatures ranging from 51.8ºF to 65.3ºF (11ºC to 18.5ºC). Healthy larvae were not produced at water temperatures of 50ºF or 75.2ºF (10ºC or 24ºC). Water temperatures below 60.8ºF (16ºC) prolonged development and reduced survival. Eggs hatched in 12 to 15 days at water temperatures of 53.6ºF (12ºC); in 6 to 8 days at water temperatures of 62.6ºF (17ºC); and in 71 to 86 hours at water temperatures ranging from 56.8ºF to 73.4ºF (13.8ºC to 23ºC) (Painter et al. 1979). Under lab conditions, the American shad incubation/temperature relationship is: Y = 729.06 – 8.75 X (r = 0.93), where Y is the number	

Element	Element Descriptor	General	Feather River Specific
		of hours required for hatching and X is the mean temperature for development (Painter et al. 1979). American shad eggs hatch in 8 to 12 days at water temperatures ranging from 51.8ºF to 59ºF (11ºC to 15ºC), and in 6 to 8 days at water temperatures of 62.6ºF (17ºC), which is considered optimal. Eggs hatch in 3 days at water temperatures of 75.2ºF (24ºC), but the survival rate decreases at these relatively high temperatures (Moyle 2002).	
size of newly hatched larvae	Average size of newly hatched larvae.	American shad larvae are 0.35 to 0.39 inches (9 to 10 millimeters) in length at hatching (Painter et al. 1979). American shad larvae are 0.24 to 0.39 inches (6 to 10 millimeters) in length. They are 0.35 to 0.47 inches (9 to 12 millimeters) in length when the yolk sac is absorbed (Moyle 2002; U.S. Fish and Wildlife Service 1995). American shad larvae are 0.22 to 0.39 inch (5.7 to 10.0 millimeters) in length (Stier et al. 1985; Wang J. 1986).	
time newly hatched larvae remain in gravel	Time of year of hatching, and duration between hatching and emergence from gravel.	American shad larvae grow and transform rapidly and are 0.9 to 1.1 inches (24 to 28 millimeters) in length in 30 to 40 days; 53 days after hatching, American shad averaged 1.1 inches (27.5 millimeters) (Painter et al. 1979; Stier et al. 1985).	
other characteristics of larvae	Alevin -- early life history phase just after hatching (larva) when yolk-sac still present.	American shad larvae are planktonic for about 4 weeks (Moyle 2002; Stier et al. 1985). American shad yolk sacs are absorbed when they reach 0.48 inches (12.2 millimeters), in about 4 to 7 days after hatching.	
timing range for emergence	Time of year (earliest-latest) hatchlings (larvae and alevins) leave or emerge from the nesting/hatching (gravel) sites.		

Element	Element Descriptor	General	Feather River Specific
timing peak for emergence	Time of year most hatchlings emerge.		
size at emergence from gravel	Average size of hatchlings at time of emergence.	American shad are 0.96 to 1.2 inches (24.3 to 30.5 millimeters) at emergence (U.S. Fish and Wildlife Service 1995).	
Juvenile rearing			
general rearing habitat and strategies	General description of freshwater environment and rearing behavior.		
water temperature tolerance for juvenile rearing	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Water temperatures for rearing juvenile American shad are lethal at 36ºF (2.2ºC), and sublethal at 39.2ºF to 42.8ºF (4 to 6ºC) in lab conditions (Chittenden Jr 1972).	
water temperature preference for juvenile rearing	Range of suitable, preferred, or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	In the Sacramento River, juvenile American shad prefer water temperatures between 62.6ºF and 77ºF (17ºC and 25ºC) (Moyle 2002).	
water velocity ranges for rearing juveniles	Reported range of observed (minimum and maximum) water velocity utilization.		
water velocities preferred by rearing juveniles	Reported range of most frequently observed water velocity utilization.		
water depth range for juvenile rearing	Reported range of observed (minimum and maximum) water depth utilization.		

Element	Element Descriptor	General	Feather River Specific
water depth preference for juvenile rearing	Reported range of most frequently observed water depth utilization.		
cover preferences for rearing juveniles	Type of cover for protection from predators used by rearing juveniles (e.g. crevices, submerged aquatic vegetation, overhanging vegetation, substrate cover, undercover bank, small woody debris, large woody debris).	In the upper Delaware River, a study found no relationship between juvenile American shad abundance and habitat type, suggesting their general use of most riverine habitats. A positive relationship was found between juvenile American shad abundance and water temperature in riffles, and also between juvenile American shad abundance and submerged aquatic vegetation (Ross et al. 1997).	
food base of juveniles	Indicate primary diet components. Also indicate the diet changes, if any, as growth occurs.	After the yolk sacs are absorbed in 4 to 5 days, American shad larvae feed on zooplanktons. American shad prefer zooplanktons over phytoplankton. During early transformation, juvenile American shad feed on ostracods, insects, insect larvae, copepods, and cladocerans. There is no change in juvenile American shad food habits in the 53 to 121 days following hatching (Painter et al. 1979). In the San Francisco estuary, young American shad feed on zooplankton, mysid shrimp, copepods, and amphipods (Moyle 2002). American shad larvae feed mainly on aquatic crustaceans, tendipedid larvae, and pupae; juveniles feed on aquatic crustaceans, tendipedid larvae and pupae, and adult insects (Levesque et al. 1972).	
feeding habits of rearing juveniles	Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder. Also indicate	Rearing juvenile American shad are opportunistic, feeding throughout the water column on bottom organisms (such as chironomid larvae) to surface insects (Moyle 2002).	

Element	Element Descriptor	General	Feather River Specific
	change of feeding habits growth occurs.	Rearing juvenile American shad are day feeders and may seek concentrations of food off migration pathways (Moyle 2002). Rearing juvenile American shad are opportunistic feeders and generally select chironomid larvae and pupae, and adult terrestrial insects (Ross et al. 1997).	
predation of juveniles	Indicate which species prey on juveniles.	In Juniata River, Pennsylvania, smallmouth bass, spotfin shiner, mimic shiner, cyprinids, and walleye consume American shad larvae (Johnson et al. 1995b).	
timing range for juvenile rearing	Range of time of year (months) during which rearing occurs.	Some juvenile American shad appear to rear in the Delta for up to one year (U.S. Fish and Wildlife Service 1995).	Season-long juvenile American shad rearing occurs in the Feather River below Yuba City (U.S.Fish and Wildlife Service 1995).
timing peak for juvenile rearing	Time of year (months) during which most rearing occurs.		
Juvenile emigration			
time spent in fresh water prior to emigrating	Duration (in years and/or months) from emergence to emigration to the ocean.	American shad spend up to one year in fresh water prior to emigrating (U.S. Fish and Wildlife Service 1995).	
water temperature tolerances during emigration	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	In the Potomac River, American shad begin emigrating when water temperatures fall to about 40.1ºF (4.5ºC) (Painter et al. 1979). When river temperatures reaches below 59.9°F (15.5°C), juvenile American shad start emigrating at Matamoras, Pennsylvania (Leggett et al. 1972).	Studies in the Feather River show that few young American shad were caught while sampling after river temperatures dropped to 59.9ºF (15.5ºC) (Painter et al. 1979).
water temperature preferences during emigration	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.		The optimum water temperature for juvenile American shad emigration is warmer than 59.9°F (15.5°C) (Painter et al. 1979).

Element	Element Descriptor	General	Feather River Specific
emigration timing range	Time of year juveniles commence emigration and duration of emigration.	Seaward migration of young-of-the-year (YOY) American shad in the Sacramento River occurs from July through mid-December, peaking in late August and September (Painter et al. 1979). In the Sacramento-San Joaquin river system, American shad emigration starts in late June and extends to November (Painter et al. 1979). American shad emigration may start as early as June in wet years when outflows are high, and continue until November (Moyle 2002).	
emigration timing peak	Time of year most juveniles are emigrating.	Seaward migration of young-of-the-year (YOY) American shad in the Sacramento River occurs from July through mid-December, peaking in late August and September (Painter et al. 1979). In the Sacramento River, American shad emigration peaks in September through November (Moyle 2002). At Matamoras, Pennsylvania, American shad emigration peaks in the fall, when river temperatures fall below 59.9°F (15.5°C) (Leggett et al. 1972).	
size range of juveniles during emigration	Minimum and maximum sizes (inches or mm) of emigrating juveniles. Indicate average size.	Emigrating juvenile American shad average 0.79 inches (20 millimeters) in length in late June and 3.15 inches (80 millimeters) in length in October (Painter et al. 1979). Emigrating American shad in the Sacramento-San Joaquin river system measure 2.17 inches (55 millimeters) in July, and reach 4.13 inches (105 millimeters) in November (Painter et al. 1979). Outmigrating American shad are 2.0 to 5.9 inches (5 to 15 centimeters) in length (Moyle 2002).	

Element	Element Descriptor	General	Feather River Specific
factors associated with emigration	Pulse flows, water temperature changes, turbidity levels, photoperiod, etc.		
Other potential factors			
DO	Levels of dissolved oxygen in water expressed in mg/l tolerated by fish.	In the Connecticut River, one study found no American shad eggs in areas with dissolved oxygen levels of less than 5.0 parts per million. In the Columbia River, the lethal dose sufficient to kill 50 percent of the eggs (LD_{50} value) was 3.5 parts per million, and was 2.0 to 2.5 parts per million for Connecticut River eggs. High percentages of normal-appearing American shad larvae occur at 4.0 parts per million (Painter et al. 1979). For American shad spawning, the dissolved oxygen level must be above 5 milligrams per liter (Moyle 2002; Stier et al. 1985).	
pH	Alkalinity/acidity of water (expressed in pH) that fish can tolerate.	The American shad LD_{50} value range for pH is 5.5 to 9.5; in the Susquehanna River, eggs developed satisfactorily at pH ranges of 6.0 to 9.4; pH below 5.2 is lethal for American shad (Painter et al. 1979).	
turbidity	Indicate turbidity or state of water (e.g., clear water or presence of siltation or organic/inorganic matter in water) that fish can tolerate.	American shad spawning areas vary from clear to very turbid in selected east coast rivers (Painter et al. 1979). In laboratory experiments, American shad larvae are much less tolerant of suspended sediments than eggs. Concentrations of suspended sediments greater than 100 parts per million significantly reduced survival of American shad larvae that were continuously exposed for 96 hours (Stier et al. 1985).	
factors contributing to mortality	e.g. fishing/angling mortality, drastic habitat alterations, unfavorable climatic changes, etc.	Water temperature and flow are the most obvious environmental factors affecting American shad (Painter et al. 1979). Several contributing factors to the declining American shad population since the 1970s are:	The following flow and temperature recommendations to maintain a normal distribution of adult American shad in the Feather River for May and June are: (1) the Feather River flow should not be less than 34 percent of the Sacramento River flow, the Yuba River should not be less than 33 percent of the

Element	Element Descriptor	General	Feather River Specific
		(1) diversion of water from the rivers and the Delta; (2) changing conditions in the ocean; (3) pesticide effects on larvae; and (4) inadequate attraction flows in major spawning tributaries such as the American River (Moyle 2002). The thermal regime in home river is the principal factor influencing American shad egg and larvae survival on the Atlantic coast. Northern populations spawning in a thermally harsh environment use energy reserves for migration, (Leggett et al. 1978). In the Susquehanna River, Pennsylvania, food deprivation of 16- and 18-day old American shad larvae (age at the onset of exogenous feeding) for as little as 2 days has significant effects on the survival and growth in laboratory experiments; to increase survival, American shad larvae should feed prior to reaching reservoir environments (Johnson et al. 1995a). In the Connecticut River, flow growth and survival of 5-day old American shad larvae is directly linked to the following conditions: low temperatures ranging from 50°F to 57.2°F (10°C to 14°C); high river flows ranging from 19,988 to 40,012 cubic feet per second (566 to 1,133 meters per second); and low densities of zooplankton 150 to 300 per cubic meter). Later cohorts are more successful at higher water temperatures and zooplankton abundance, and lower river flows (Crecco et al. 1985). There is evidence that the number of spawning American shad spawning is directly proportional to the flows at the time the shad arrive. American shad are also capable of adjusting the timing of runs to the timing of river outflows; the date when 50 percent of American shad migrated past Bonneville Dam is correlated with the shift in thermal and flow regimes (Quinn et al. 1996).	Feather River flow, and the American River flow should not be less than 10 percent of the Sacramento River flow at Sacramento; and (2) water temperature should be maintained between 60.8°F and 69.8°C (16°C and 21ºC) in the upper Sacramento, Feather, Yuba, and American rivers (Painter et al. 1979).

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